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ABSTRACT

One of twelve water treatment technology units, this student manual on general plant operations provides instructional materials for seven competencies. (The twelve units are designed for a continuing education training course for public water supply operators.) The competencies focus on the following areas: water supply regulations, water plant parts diagram, water sources, monthly operation reports, daily demand variation, average water reserve, and water shutoff guide. For each competency, student objectives, resources (e.g., information sheets, forms, appendix materials, and references to manuals, pamphlets, or books), learning activities, and evaluation activities are provided. The appendices contain information sheets on storage, sources of water, records and reports, and record-keeping, calculations and simple hydraulics. Generally, an evaluation form with answer key is provided for each competency. (JH)

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Water Treatment Technology

GENERAL PLANT OPERATION

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December, 1978

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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CE022 323

GENERAL PLANT OPERATION

EVALUATOR'S COPY

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EVALUATOR'S INSTRUCTIONS

Name _____

Address _____

_____

Phone _____

This is your EVALUATOR'S COPY of the GENERAL PLANT OPERATION unit. It contains all of the materials received by the operators who will be working on the unit. It also contains *answer keys* and *directions* for the evaluation of each Competency. For each Competency Sheet, there is a COMPETENCY, a list of RESOURCES, LEARNING ACTIVITIES, and EVALUATION ACTIVITIES.

Your student operators will call you when they are ready to be evaluated. An operator may complete the evaluations in *any* order. S/he may choose to complete one at a time, or several at one time. *It is up to you and each operator to set convenient schedules for the evaluations.* It is important that the operators learn the skills listed in each competency. It is <u>your</u> job to be sure the operators can perform the competencies.

If an operator does <u>not</u> complete an evaluation correctly, s/he may try again later after practicing the skills. It would be helpful for you to tell the operators just how they should improve their knowledge and skills in order to complete the evaluation successfully. Be sure to call if you have any questions.

This package contains:

----- General Plant Operation Unit
----- Evaluation Forms for each Competency

You will receive instructions as to where to send the completed evaluation forms. Please be sure that the operator's name and your name are on the forms, as well as the date on which the evaluation was performed.

INSTRUCTIONS FOR THE STUDENT OPERATOR

The GENERAL PLANT OPERATION unit contains seven competencies. A "competency" is a skill that is necessary for good on-the-job performance. Each competency in this unit is necessary for you to perform on the job according to the West Virginia Department of Health. There is a Competency Sheet to help you understand each competency.

DIRECTIONS FOR COMPLETING THE UNIT:

1. Read each Competency Sheet carefully. Every Competency Sheet contains:

   COMPETENCY
   Objectives
   RESOURCES
   LEARNING ACTIVITIES
   EVALUATION ACTIVITY(IES)

2. After reading the whole Competency Sheet, you should understand what will be expected of you.

3. Do the LEARNING ACTIVITIES that you think will help you the most. This may include reading some of the RESOURCES which have been included with the unit.

4. If you need additional help, ask an operator in your plant for assistance, or call your evaluator; he's there to help you

5. When you are ready to complete the EVALUATION ACTIVITY for one or more competencies -- call your evaluator. The two of you will schedule the best time for your evaluation.
   a. If you complete the evaluation correctly, go on to the next competency.
   b. If you do <u>not</u> complete the evaluation correctly, your evaluator will tell you what your mistakes were. You must go back and practice your skills and read the RESOURCES again. Call your evaluator when you are ready to try again. *You must wait at least one week before being re-evaluated on a competency.*

6. When you complete all your evaluations correctly you will receive a Certificate of Accomplishment and 1.4 Continuing Education Unite of Credit.

7. If you want to go on to another unit, contact your evaluator for the materials. The procedure will be similar for all units.

AN EXPLANATION OF CONTINUING EDUCATION UNITS

For student operators in the OPERATOR-IN-TRAINING category who will be taking the certification examination for Class I, this course is an opportunity to increase your knowledge and competence in the treatment of water for human consumption. Successful completion of the manuals will also, it is hoped, make passing the certification exam much easier. The Continuing Education Units which you will get by taking this course will not decrease the minimum one year operating experience requirement for a Class I certificate.

For student operators who now hold a Class I certificate, the completion of all twelve manuals in the course will reduce the currently required three years of total operating experience for Class II certification by approximately four months. Thus, if you complete the course, you will need only two years and eight months of total operating experience before you take the Class II exam.

Here is a listing of the Continuing Education Unit (CEU) value of each of the manuals.

Manual	CEU Value
General Plant Operation	1.4
Taste, Odor, and Color	0.6
Chemistry/Bacteriology	2.5
Chlorination	2.5
Fluoridation	0.6
Filtration	1.2
Hydraulics	0.6
Distribution Systems	1.2
Pumps	0.6
Wells	1.0
Cross Connections	0.4
Springs	0.4
Total	13.0

For comparison with other types of training previously available, the CEU conversions below are given.

Public Water Supply Operator's Short Course (given by State Department of Health Personnel)	4 CEUs
One Semester Hour of College Credit	1.5 CEUs
One Year of College Credits (30 semester hours)	45 CEUs

COMPETENCY: State your legal responsibility as a plant operator for providing drinking water to your customers.

Objective: Define drinking water.

Objective: Become familiar with all W. Va. Public Water Supply Regulations.

RESOURCES:

(a) Pamphlet: Public Water Supply Regulations adopted by the West Virginia State Board of Health.

LEARNING ACTIVITIES:

(a) Read the W. Va. Public Water Supply Regulations. Note which regulations specifically affect you and your water treatment plant.

(b) Become familiar with how to use the regulations. For example-- if you want to know how the regulations affect bottled water plants, where would you look for information?

It is not important for you to memorize the regulations. You should know how to refer to the regulation pamphlet when you have questions.

EVALUATION ACTIVITY: Complete Evaluation Form #1. *Use the W. Va. Public Water Supply Regulations as a reference.* You must answer every question correctly. You must show which regulation number relates to each question.

(General Plant Operation #1)
Evaluation Form
EVALUATOR'S COPY

Operator _____

Evaluator _____

Date _____

USE YOUR W. VA. PUBLIC WATER SUPPLY REGULATIONS AS A REFERENCE.

Directions: For each item write "True" or "False" and the regulation number that relates to the question. If you answer "False" write the correct answer on the lines under the question.

1. True
Reg.# 6.1 You are not allowed to use any kind of disinfectant except chlorine (except with special permission).

2. False
Reg.# 10.1 Water supplied to the consumer must not exceed 5 units of turbidity for a monthly average.

Turbidity is not to exceed 1 NTU for a monthly average nor 5 NTU based on an average for any two consecutive days.

3. False
Reg.# 4.2 It is alright to operate a treatment plant for a short while without a permit.

No one can operate or maintain a water treatment plant in W. Va. without a permit.

4. False
Reg.# 6.2 The minimum contact time for chlorine is 20 minutes to the first consumer.

The minimum contact time for chlorine is 30 minutes to the first consumer.

5. False
Reg.# 6.6 Water samples for bacteriological analysis may be collected in any glass bottle as long as it is clean.

Samples should be collected in bottles provided by the State Lab.

6. True
Reg.# 14.1 Records of your treatment plant operation should be stored at your plant for at least five years.

7. True — A system which has 14 service connections and serves 43 year-round residents is a community water system.
Reg.# 2.13

8. True — Violation of any W. Va. Public Water Supply Regulation may be punished by a $200 fine.
Reg.# 22

9. True — A trace of chlorine residual must be maintained throughout the distribution system.
Reg.# 6.5

10. True — Exemptions from an existing maximum contaminant level requirement cannot be obtained for a new public water system.
Reg.# 16.1

11. False — An operator does not need to report a ten hour breakdown of the chlorination equipment at his plant. *Failure to comply with any drinking water regulation must be reported within 48 hours.*
Reg.# 12.2

12. True — The W. Va. State Department of Health has the authority to order a treatment plant to change the source of the water supply.
Reg.# 3.5

13. True — Fluoridated and defluoridated water supplies must be analyzed at least once a day to determine fluoride concentration.
Reg.# 19.3

14. True
Reg.# 6.7
For a population of 5,000, at least seven samples should be examined bacteriologically each month.

15. False
Reg.# 7.2
The maximum contaminant level for Lead is 0.5 mg/1.
The maximum contaminant level for lead is 0.05 mg/l.

16. True
Reg.# 14.1
Records of microbiological, turbidity, and radiological analyses of your water must be kept at or near your plant for a period of five years after the tests were performed.

17. False
Reg.# 14.5
Records concerning a variance from the maximum contaminant level for Lindane must be kept for five years after the variance was granted.
Records concerning a variance must be kept at least five years beyond the expiration of the variance.

18. True
Reg.# 14.1
You must keep operational and control test records for five years and chemical analysis records for ten years.

COMPETENCY: Sketch and label a diagram which represents the basic parts of your water treatment plant.

Objective: Become familiar with all of the basic parts of your water treatment plant and how they relate to each other.

Objective: Describe the process water goes through as it is treated at your plant.

RESOURCES:

(a) Blueprints of your water treatment plant (if available).

(b) THE STORY OF WATER SUPPLY by "Willing Water", American Water Works Association. (Supplied with unit.)

(c) Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Health Education Service, P.O. Box 7283, Albany, N. Y. 12224.

LEARNING ACTIVITIES:

(a) Take a "tour" of your treatment plant. Notice where all the major parts (pumps, filters, feeders, etc.) are located. How does one part relate to all of the other parts? In what direction does the water move through your plant?

(b) Sketch a diagram including all the major parts of your treatment plant. Be sure to include all major parts such as settling basins, chlorinators, filters, etc.

You don't have to be an artist. It is not necessary for your drawing to be to scale. The general plan of your plant and the relationship among the parts is required for this competency.

Label the parts you have drawn. Draw arrows to show the direction water flows through your plant. It may help to refer to your plant blueprints if they are available.

EVALUATION ACTIVITY: Sketch and label all the basic parts of your water treatment plant. Draw arrows to show the direction water moves through your plant.

The following parts should be included in your sketch if they appear in your plant:

water source	filter
pumps	chlorinator
chemical feeders	clear well
mixing basin	storage tank
sedimentation basin	reservoir

(General Plant Operation #3)
Competency Sheet

COMPETENCY: Identify the sources of water available to your treatment plant.

Objective: Identify three different types of water sources.

Objective: Identify all possible water sources which could feed into your treatment plant if necessary.

RESOURCES:

(a) Manual of Instruction for Water Treatment Plant Operators, New York State Dept. of Health, Health Education Service, P. O. Box 7283, Albany, New York 12224, Chapter 2.

(b) Correspondence Course Manual for Water Plant Operators Class D, 2nd Edition, The South Carolina Water and Pollution Control Association, 1968, pp. 164-174. *-Gold Appendix-*

LEARNING ACTIVITIES:

(a) Read the recommended Resources listed above to find information about water sources.

(b) Identify the source(s) of water presently entering your treatment plant.

(c) Identify additional sources of water which could be made available to your treatment plant if necessary. The W. Va. department of Natural Resources may have information which would be useful to you. The United States Geological Survey and the W. Va. Economic and Geological Survey (in Morgantown) may also have helpful information. You may want to request information and topographical maps of your area which will show surface and underground water sources.

EVALUATION ACTIVITY: Complete Evaluation Form #3. You may use references. You will be expected to (a) identify the source(s) of water presently entering your treatment plant, and (b) identify potential alternative source(s) of water.

(General Plant Operation #3)
Evaluation Form
EVALUATOR'S COPY

Operator _____

Evaluator _____

Date _____

1. List and describe the source(s) of water presently entering your treatment plant.

Source		Description
Example:	*Well*	*Artesian. Underground pump used.*
Example:	*Indian River*	*Generally high turbidity. Pollution from nearby chemical plant.*
Example:	*Lake Gloomy*	*Also used for city sewage discharge.*

2. Describe what you did to identify alternative sources of water for your treatment plant.

Examples: Explored local area; researched history of area's water sources; contacted W. Va. Department of Natural Resources for information; etc.

3. Describe all of the alternative sources of water that could be made available to your treatment plant if necessary.

Source		Description
Example:	*Green River*	*Highly polluted with industrial waste but could be used if necessary.*
Example:	*Lake Local*	*Was used as water source about 20 years ago.*
Example:	*Springs*	*Extensive construction necessary to bring water to plant, but feasible.*

COMPETENCY: Accurately complete the "Monthly Operation Report" required by the W. Va. Department of Health.

Objective: Learn how to identify and describe each of the factors listed on the form.

Objective: For each day of the month, accurately record information for all factors on the "Monthly Operation Report".

RESOURCES:

(a) "Monthly Operation Report" supplied with unit. Note: There is one report form for Class I plants and one report form for Class II & III plants. Be sure to complete the form that applies to your treatment plant.

(b) Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Health Education Service, P.O. Box 7283, Albany, New York 12224, Chap. 18. *-Blue Appendix-*

LEARNING ACTIVITIES:

(a) Review the "Monthly Operation Report" that is to be completed for your treatment plant (Class I or Classes II & III).

(b) For every day of the month, you must accurately fill in all spaces. Remember to complete both sides of the report form.

You do not need to wait until the first day of a month to begin the report form. If you are ready to begin, write in the correct dates in the "Date" column on the left. Once you begin, you must complete the form for 30 consecutive days.

EVALUATION ACTIVITY: Your completed "Monthly Operation Report" will be checked by your Evaluator. Make sure that you have completed all blanks on both sides of the report form. Your Evaluator will check your accuracy.

EW-103
Revised 1/78

MONTHLY OPERATION REPORT
CLASS I PUBLIC WATER SUPPLY

Month_____, 19___

Name of Water System _____

Town or Facility Served _____ County_____

Date	TOTAL* Time Pumped (Hrs.)	TOTAL Water Treated (Gal.)	CHEMICALS USED		ANALYTICAL RESULTS (Mg/Liter)				
			Chlorine Dry - lb Liquid-oz	Corrosion Control (Pounds)	Chlorine Res. Plant Free	Chlorine Res. System Total	Alkalinity	Corrosion Control Chemical	pH
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									
11.									
12.									
13.									
14.									
15.									
16.									
17.									
18.									
19.									
20.									
21.									
22.									
23.									
24.									
25.									
26.									
27.									
28.									
29.									
30.									
31.									
Total									
Average									

* Individual Well Pumping Logs on back of this sheet.

Type Chemical Used:
Chlorine; Gas ☐, Hypochlorite ☐ - _____ (Name)

DPD Test Kit:
Make_____

Corrosion Control Chemical; _____ (Name)

Model_____

SUBMITTED BY: _____, Certificate: Class____No.____

Telephone Number: _____

Please note operating problems, shutdowns, etc. under "Remarks" on back of this sheet.

RETURN TO: Division of Sanitary Engineering/State Department of Health/
1800 Washington Street, East/Charleston, WV 25305,
within one week after end of month. 17

INDIVIDUAL WELL PUMPING LOG
(Time Pumped in Hours)

Date	Well #1	Well #2	Well #3	Well #4	Well #5	Total
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						
21.						
22.						
23.						
24.						
25.						
26.						
27.						
28.						
29.						
30.						
31.						
Total						
Average						
Capacity (gpm)						

Remarks:

EW-90
Revised 1/78

MONTHLY OPERATION REPORT
CLASS II & III PUBLIC WATER SUPPLIES

Month _____ 19____

Name of Public Water Supply _____ County _____

Town or Facility Served _____

DATE	Time Plant Oper. (Hr.)	CHEMICALS USED (Pounds)										FILTERS			
		LIME	SODA ASH	ALUM	FLUORIDE					CHLORINE PRE.	CHLORINE POST	WATER FILTERED 1000 Gal.	SURFACE USED Sq. Ft.	NUMBER BACKWASHED	BACKWASH WATER 1000 Gal.
1															
2															
3															
4															
5															
6															
7															
8															
9															
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22															
23															
24															
25															
26															
27															
28															
29															
30															
31															
Total															
Ave.															

19

20

DATE	ANALYTICAL RESULTS (Mg/Liter)															REMARKS
	Chlorine Residual		pH		Alkalinity		Hardness as $CaCO_3$		Iron		Fluoride	Turbidity				
	Plant (Free)	System (Total)	Raw	Fin	Raw	Fin	Raw	Fin	Raw	Fin		Raw (NTU)	Fin (NTU)			
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
13																
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24																
25																
26																
27																
28																
29																
30																
31																
Total																
Ave.																

Number of Filters_____; Total Filter Surface Area_____(Sq. Ft.); Ave. Filter Run_____(Hr.); Per Cent Wash Water_____(%)
Date Settling Basin or Clarifier Last Cleaned_____; Fluoride Compound used_____
DPD Test Kit: Make_____ Model_____; Nephelometer: Make_____ Model_____
SUBMITTED BY:_____, Operator Certificate: Class_____No._____Telephone Number:_____

RETURN TO: DIVISION OF SANITARY ENGINEERING/STATE DEPARTMENT OF HEALTH/1800 WASHINGTON STREET, EAST/ CHARLESTON, W. VA. 25305, WITHIN ONE WEEK AFTER END OF MONTH.

COMPETENCY: Using data gathered over a one week period, draw a graph showing the daily variation in water demand for your system.

Objective: Determine how to measure the amount of finished water leaving your plant in a 24-hour period.

Objective: Record the amount of finished water leaving your plant for seven consecutive days.

RESOURCES:

(a) Graph paper (included).

(b) Waterworks Manual - basic, Coordinating Council for Occupational Education, State of Washington, 1972, pp. 79-81. *-buff appendix-*

(c) Water Works Operators Manual, Third Edition, 1972, Alabama Department of Public Health, Bureau of Environmental Health, Montgomery, Alabama, Chapter XXVI, pp. 1-5, 17-18. *-Green Appendix-*

(d) Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Health Education Service, P.O. Box 7283, Albany, New York 12224.

LEARNING ACTIVITIES:

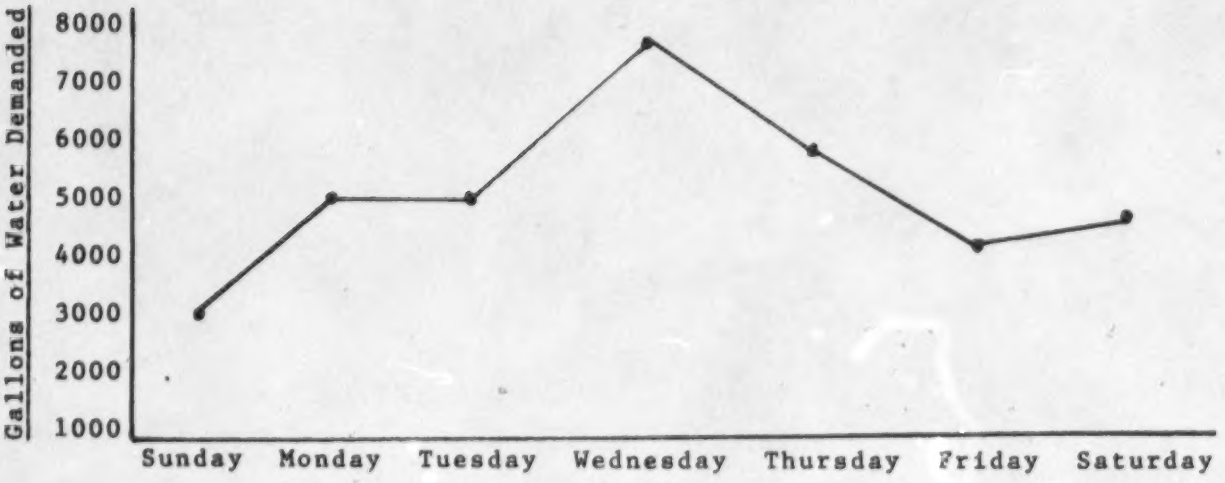
(a) To begin, measure and record the amount of finished water present in your storage tank(s). At the same time the following day take the same measurement. Repeat for a week. Each day note the level of finished water available. Subtract the amount of water which is treated. For example: if you treat 1,000 gallons of raw water on Monday and the amount of finished water drops from 5,000 gallons to 4,500 gallons that would mean there was a demand for 1,500 gallons.

You start with	5,000 finished gallons
And treat	+1,000 raw gallons
You now have	6,000 gallons
Your daily record shows a drop to	-4,500
This means the actual demand equals	1,500 gallons

If your plant does not have a master meter, the amount of water treated may be computed from the rate of pumping and the hours of pumping. See Green Appendix.

(b) Record your water demand for seven consecutive days.

(c) Using graph paper, show the daily variation in water demand for your plant. Your graph may look something like this:



Notice that the greatest demand for water was on Wednesday. If the operator made a graph like this for several weeks and found that demand was always greatest on Wednesdays, s/he could be prepared. Perhaps local industry was the cause of the sharp rise. It would be wise to check. The operator could then anticipate the increased demand and be sure to keep plenty of treated water available all of the time.

EVALUATION ACTIVITY:

You must show your Evaluator two things to be evaluated: (1) Your records of the amount of water treated and the amount of finished water leaving the plant each day for a week, and (2) Your graph which shows the daily variation in demand.

Your Evaluator will check to see that your calculations are correct.

COMPETENCY: Determine the average amount of "reserve" water which should be kept available for your system.

Objective: Determine the daily variation in demand for your system. *(See General Plant Operation Competency #5.)*

Objective: Determine the minimum amount of "reserve" water which should be available at all times.

RESOURCES:

(a) Completed graph from General Plant Operation Competency #5.

(b) Water Works Operators Manual, Third Edition, 1972, Alabama Department of Public Health, Bureau of Environmental Health, Montgomery, Alabama, Chapter XXVI, pp. 1-5, 17-18. *-Green Appendix-*

(c) "STORAGE" from Waterworks Manual - basic, Coordinating Council for Occupational Education, State of Washington, 1972, pp. 79-81. *-Buff Appendix-*

LEARNING ACTIVITIES:

(a) Complete another graph like the one made for General Plant Operation Competency #5. Record the water demand for at least one additional week.

(b) Compare your water demand graphs. Are there any *patterns* of demand? For example- is less water consumed on weekends? Are there certain days where the demand rises sharply?

Determine how much water is consumed on days when the demand is *lowest* and when the demand is *highest*.

(c) Record how much "reserve" finished water is available when the demand is *highest*. Is there enough reserve available on these days to cover an emergency, such as a main break or fire?

(d) Add up the demand for every day during one typical week. Now divide that total by 7 (number of days in a week). This is the *average daily demand* for one week.

Using your records and graphs for references determine the *minimum* "reserve" you should have available at all times. Remember to take into account the possibility of emergencies.

Now total the amount of "reserve" available for each day in one week. Divide by 7. This is your *average daily reserve* for one week. Is your *average daily reserve* larger than the *minimum daily reserve* you determined above? It should be. Your average reserve should always be large enough to account for all demand including emergencies.

If your *average daily reserve* came to less than the *minimum daily reserve* you determined above, calculate the difference. Determine how much additional water should be treated each week so that the *average daily reserve* is equal to or greater than the *minimum daily reserve*.

EVALUATION ACTIVITY: You will need to bring your water demand graphs, records, and calculations. Show your Evaluator how you calculated the *average daily reserve* which should be kept available at your plant. Remember: it should be large enough to cover emergencies. Your Evaluator will check your calculations.

COMPETENCY: Describe the procedure you would follow to inform the public if you knew ahead of time that the water would have to be shut off for a period of time.

Objective: Describe several situations which would require that local water be shut off temporarily.

Objective: Identify reasons for notifying public *in advance* when water must be shut off temporarily.

RESOURCES: (a) "Water Shut Off" Resource Sheet.

LEARNING ACTIVITIES:

(a) Check to see if there is a standard procedure for notifying the public of shut offs which has been followed in the past by your treatment plant.

(b) Identify at least three reasons why it is important to notify the public *in advance* of a water shut off whenever possible.

(c) Prepare a hypothetical written statement to be read on the radio which would notify the public of an impending shut off. Be sure to include the date, specific time, and brief explanation for the shut off.

EVALUATION ACTIVITY: Given a hypothetical (possible) situation, you will be expected to prepare a written statement to be read on the radio which will accurately notify customers of an impending shut off.

WATER SHUT OFF

Listed below are some reasons for notifying the public in advance of an impending water shut off:

1. Drinking water can be set aside in containers.

2. Infant formulae may be prepared in advance.

3. Baths and showers can be rescheduled.

4. Dishwashers, washing machines can be turned off.

Listed below are some sources you might choose to notify the public in advance of a water shut off:

1. Local radio station(s).

2. Local television station(s).

3. Use local newspaper for notification if you can plan at least one day in advance.

(General Plant Operation #7)
Evaluation Form
EVALUATOR'S COPY

Operator _____

Evaluator _____

Date _____

You receive a call from the manager of a local construction firm. He tells you that in the process of constructing a highway, the main distribution line to that part of town was accidentally broken. You must shut off the water to a nearby residential section in order to repair the line.

Write a statement to be read on the local radio station which will accurately inform your customers of the situation. You must include the date, approximately how long the water will be off, and a brief description of the situation. Write your statement below:

Check to see that the following criteria are met:

(a) Date mentioned.

(b) Estimated length of shut off mentioned.

(c) Brief description of situation included.

(d) Is the statement clear? Will the customers understand the situation as described in the statement?

(e) If other suitable sources are available, make sure they are mentioned.

STORAGE*

Water is stored for several purposes: to equalize pumping rates, to equalize supply and demand over periods of high consumption, to provide the large volumes of water required for fighting fires, and to provide some emergency reserve of water should the supply system fail. Storage may be in ground-level reservoirs with the water being pumped into the distribution system as needed, or it may be in elevated tanks that "float" on the system. An alternative to the elevated tank is the reservoir located at ground level, but on a hill or rise above the area served, thus effectively serving as an elevated tank.

SIZE REQUIREMENTS

The size of distribution system storage reservoirs depends on the normal system demands, the fire demands, and the use for which the reservoir is intended.

Variation of System Demand

The capacity of a reservoir designed to equalize the variation in daily system demand depends on the water use habits of the system served. Fig. IV-8 shows a typical variation of system demand during a 24-hr. period.

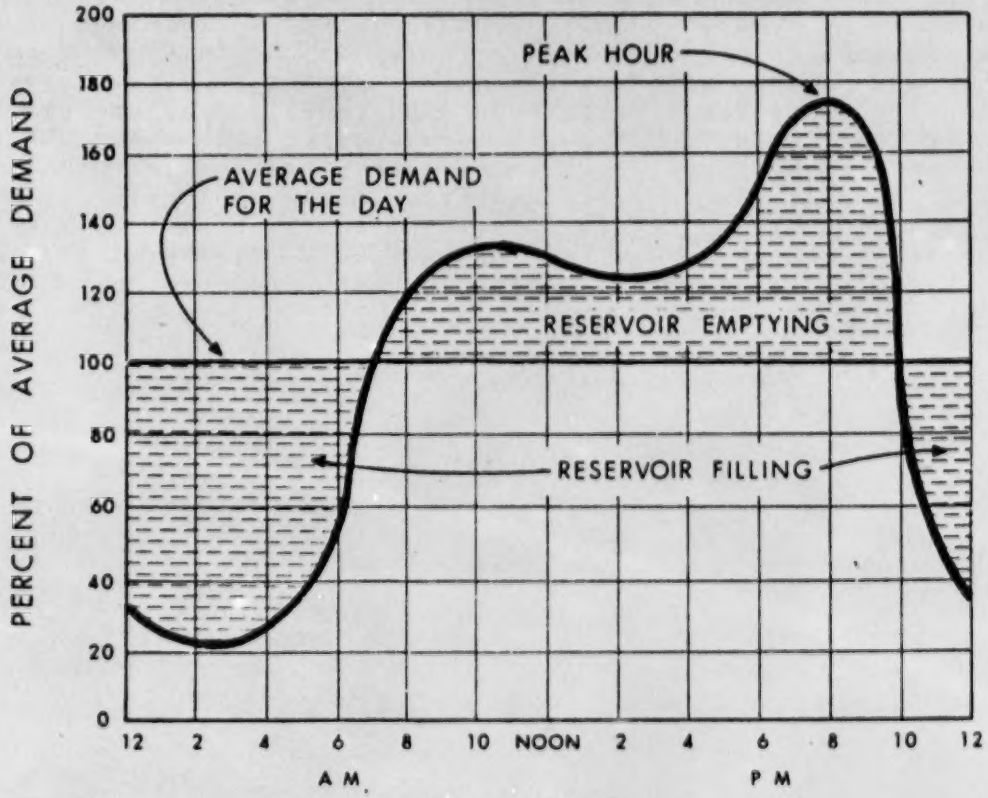


Fig. IV-8 Typical Daily Variation of System Demand

*Source: Waterworks Manual - basic, Coordinating Council for Occupational Education, State of Washington, 1972, pp. 79-81.

The reservoir normally fills during the low-demand periods at night and early morning and empties during the day and early evening. Storage requirements due to system demand fluctuation will range from 15% to 35% of the total daily demand, with 25% being an average for most systems. Since the storage reservoir must be built to provide for fluctuations on the day of maximum demand, this demand figure should be used as the basis for sizing the reservoir. Fire storage requirements will raise the total storage requirements to 30% to 40% of maximum-day demand.

Fire Storage

Storage for firefighting purposes is a function of the fire flow required and the duration for which it is to be supplied. A city with a population of less than 1,000 is, by AIA standards, required to have a fire flow of 1,000 gpm for 4 hr. duration, which would require a fire storage capacity of 240,000 gal. Minimum residential requirements would be 500 gpm for 2 hr. or a volume of 60,000 gal.

Emergency Reserve

A storage reservoir sized exactly to the volume required for equalization of daily demand would leave no room for an increase in demand or for emergencies of any nature. The system would soon be out of water if any portion of the water supply system failed to operate continuously. The water system would be penalized by the AIA grading system if records showed that the fire storage volume was not available at all times. Therefore, an emergency reserve is normally provided in the system storage facilities. Again, the specific requirements depend on the system to be served and the reliability of other components in the water system. An emergency reserve storage capacity equal to the maximum-day demand is not uncommon.

RECORDS, CALCULATIONS

AND SIMPLE HYDRAULICS*

Water plant records are indispensable to economic and efficient operation of the plant. Records covering the total water filtered, total wash water, and chemicals used make possible the detection of wasteful operation by comparison either with previous records or with results obtained by other plants. Data showing the condition of the raw water available in previous months and years not only justify the use of certain quantities and kinds of chemicals but also are valuable for determining the dosages when similar waters occur. Information on finished water is valuable in order to determine if the water processed was satisfactory from a chemical standpoint and if it was adequately disinfected. It is only by keeping a record of the water treated and utilized at the plant that the losses, or "unaccounted-for" water can be determined.

Even though the Health Department printed the record forms and requires that they be kept they are of much more value to the operator or town than to the Health personnel. Therefore, do not wait until the end of the month and then copy figures into the record that are meaningless or false. If the tests are not made so that true figures can be obtained and the quantity of water treated is not recorded, let your report show that no record was kept. Leave the spaces blank if the tests were not made, the chemical not weighed or the water is not measured.

The record form furnished by the Health Department should be used and kept at all water treatment plants. The original should be retained and a copy of this form should be sent to the Health Department at the end of each month. Well kept records may be of great benefit to the operator and the city. This record is used by the Health Department only to help answer questions or complaints relative to a particular plant's operation. The records are kept in a permanent file and can be used to prove that the treatment operation was properly carried out, should question arise. The operator's signature appears on the report and this indicates that he stands behind the report and certifies that the data recorded thereon is correct. Unless he knows the tests, weights and measures were actually made he should enter only those figures he knows are correct and true. The report forms may be obtained by request to the Health Department.

The manager or superintendent should be provided with an accurate record so that he can make a study of cost of operating the plant. Using the record of the amount of water treated, he determines how much water is delivered to the system but not accounted for. Therefore, it can be seen that daily operational reports are for management, operators and Health Department alike.

*Source: Water Works Operators Manual, Third Edition, 1972, Dept. of Public Health, Bureau of Environmental Health, Montgomery, Alabama, Chapter XXVI, pp. 1-5, 17-18.

Concerning "unaccounted-for" water---a reasonable figure for the percentage of "unaccounted-for" water in small distribution systems will vary from system to system. Factual reports indicate that some systems are "losing" more than 50% of the water produced. In some instances this apparent loss may be due to water furnished churches, schools, hospitals, or city owned and operated facilities without charge or meters. Even if water is furnished free to such service connections, they should be metered. For a compact system, a reasonable figure of "unaccounted-for" water might be about 15%. In a "tight", well-operated system, this may be reduced to ten percent. If the losses start increasing and continue to rise, this should be an indication that the "unaccounted-for" water is increasing and a search should be begun for leaks and breaks in the system.

Another type record that should be maintained and kept up to date is a map of the distribution system. This map or maps should indicate the main size, location of valves, meters, fire hydrants, stand pipes, storage tanks, elevation markings, etc. An up to date distribution map is a must for a well-operated water system. All valves, fittings, and location of mains should be accurately recorded by references to permanent reference points. These records and maps should give detailed information on a valve as to its make, size, number of turns necessary to close, date of installation, maintenance record, etc. Similar records should be kept on other equipment. The location of mains should be carefully recorded. If this was not made when the main was installed, notes should be made at every opportunity, when repairing a break, tapping for service line, etc. These notes should then become part of the permanent record.

Records should be established and maintained on the maintenance of equipment. This will allow the operating personnel to establish a preventative maintenance schedule on all items of equipment, i.e., pumps, motors, chemical feeders, chlorinators, etc. By establishing a regular schedule for preventative maintenance (regular inspection, greasing, oil change, etc.) downtime and emergency repairs will be virtually eliminated.

CALCULATIONS

Prior to going into the details of the calculations that all water works men should be able to handle, a few basic items will be reviewed.

In order to correctly solve a problem the operator must assure himself that all units of measure have been converted to the proper unit required for the formula with which he is working. Examples of some units the operator will be using are: grains per gallon, grams, ounces, pounds, cubic feet, square feet, liters, gallons, parts per million, pounds per square inch, etc. A table of useful conversion factors is found at the end of this chapter.

Units of time are important in water calculations. To convert gallons per minute into gallons per hour, one must, of course, multiply by 60. If one needs to know gallons per day, when gallons per minute are known, multiply gallons per minute by 1440. This is the number of minutes in a day (24 x 60).

One item that is usually confusing is the transposing of items in a formula. For instance, in the formula A = B x C, there should be no difficulty in finding "A". However, suppose the value of "A" is known and the value of "B" or "C" is needed. To find "B" the equation becomes $B = \frac{A}{C}$ and to find "C" the equation is $C = \frac{A}{B}$.

The rule for transposing, as shown above, is that whenever an equation is changed, the same operation must be performed on both sides of the equation. In the above example, in order to find "B" both sides of the equation were divided by "C" which gave A ÷ C = B x C ÷ C, (this may also be written $\frac{A}{C} = \frac{B \times C}{C}$.) When this operation is solved, the answer becomes $\frac{A}{C} = B$, or $B = \frac{A}{C}$.

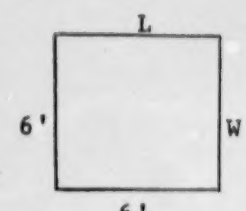
The above rule also applies to multiplication, addition, and subtraction. Whatever is multiplied, added, or subtracted on one side of an equation must be added, subtracted, or multiplied on the other. For example, in the equation X = Y + Z, if it is desired to know the value of "Z", then subtract "Y" from both sides, In this form, the equation becomes X - Y = (Y + Z) - Y. Perform the subtraction and the answer is X - Y = Z or turn it around, Z = X - Y.

The operator has many occasions to compute areas of surfaces and volumes of various shaped tanks and to solve other arithmetical problems. Most of these problems involve simple arithmetic operations, but the factors to be employed sometimes evade the mind since they may not be used often. As reference and refresher material the method of computing certain areas and volumes follows.

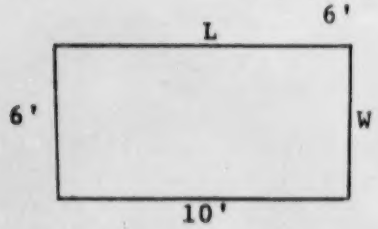
Area, as illustrated below, is the product of two dimensions or measurements: length multiplied by width. Area is the number of square units of a surface, for example the square feet of a floor surface. Volume is the product of three dimensions: length times width times depth, or to state it another way, the product of the area of the bottom times the depth. Volume is the space enclosed in a box, room, tank, piece of pipe, etc. It states how much the object will hold and is usually expressed in cubic feet.

Area and Volume of Square or Rectangular Figures:

Example: Area

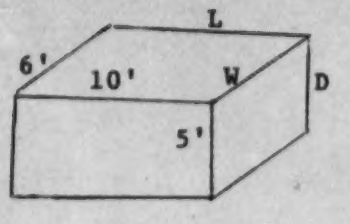


Length x Width = Area
L x W = Area
6' x 6' = 36 sq. ft. or
72" x 72" = 5184 sq. in.



Length x Width = Area
10' x 6' = 60 sq. ft.

Example: Volume

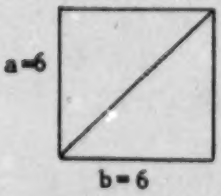


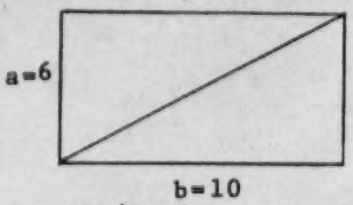
Volume equals Length times Width times Depth
V = L x W x D
V = 10' x 6' x 5'
V = 300 cubic feet

(Unless great accuracy is desired the operator should consider 7.5 gallons as being equal to 1 cubic foot. Actually, 1 cubic foot of water is 7.481 gallons.) Thus the volume of the tank above (6' wide, 10' long, 5' deep) would hold 2250 gallons. (10' x 6' x 5' x 7.5 = 2250 gallons or 300 cubic feet x 7.5 gallons = 2250 gallons).

Area of Triangles:

A triangle is usually 1/2 of a square or rectangle.



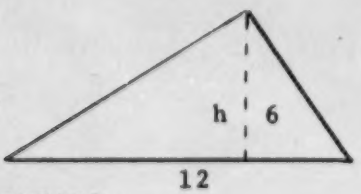


Naturally, the area is equal to 1/2 the area of the square or rectangle. Hence, the formula for the area is half the base (b) times the altitude (a) (height).

A = 1/2 b x a
A = 1/2 6 x 6
A = 18 square feet

A = 1/2 b x a
A = 1/2 10 x 6
A = 30 square feet

A = 1/2 b x h
A = 1/2 12 x 6
A = 36 sq. ft.

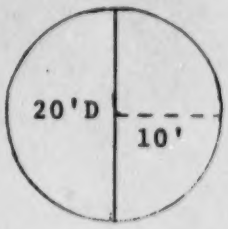


Area and Volume of Circular Figures:

Concerning circles, several new terms are used. The distance across a circle through the center is the diameter, D . Half the diameter is called the radius, r . A number, 3.1416, is known as pi (pronounced pie) or the symbol π .

Pi, which equals 3.1416, is sometimes shown as 3.14, 3 1/7 or 22/7. Another new term is the word "squared". When a number is squared, it is multiplied by itself. Thus 2 squared is 2 x 2 or 4. This is also written $2^2 = 4$; 4 squared is 4 x 4 = 16, or $4^2 = 16$.

The Area of a circle equals the radius r , half of diameter, squared times pi.



$A = 3.1416 \times r \times r$ or
$A = \pi r^2$

Example: Find Area of a circle with a 20 foot diameter:

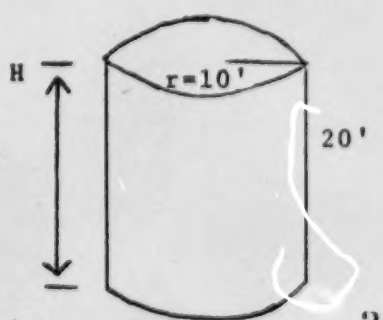
$A = \pi r^2$
$A = 3.1416 \times 10^2$
$A = 3.1416 \times 10 \times 10$
$A = 314.16$ sq. ft.

The volume of a cylindrical tank is the amount of space in it or the quantity it will hold. Like finding the volume of a room, the area of the surface of the floor multiplied by the depth will give the volume. The volume equals pi times the radius squared times the depth, or the area of bottom times the depth. The formula for the volume is: $V = \pi r^2$ x depth (remember πr^2 is the area of a circle).

Example: Find the volume of a tank 20 feet in diameter and 20 feet deep or high. Thus $3.14 \times 10^2 = 3.14 \times 10 \times 10 = 314$ square feet which is the area of the tank bottom. Next multiply the area by the depth and obtain the volume: 314 sq. ft. x 20 ft. = 6280 cu. ft.; or it can be carried out in one operation, for example:

$V = \pi r^2 \times$ Depth
$V = 3.14 \times 10 \times 10 \times 20 = 6280$ cu. ft.

To find the number of gallons the tank will hold, multiply the volume in cubic feet by the number of gallons in one cubic foot (7.5): 6280 cu. ft. x 7.5 gal. per cu. ft. = 47,100 gallons.

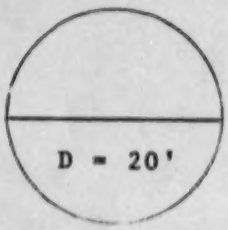


Circumference of Circles

The distance around a circle is called the circumference or perimeter. The circumference (C) may be determined by measuring the diameter and doing a little arithmetic. This measurement (the diameter) multiplied by Π or 3.14 equals the circumference.

Example: Find the circumference of a circle 20 feet in diameter.

$C = \Pi D$
$C = 3.14 \times 20$
$C = 62.8$ feet

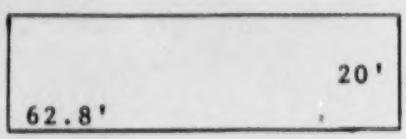


C = 62.8'

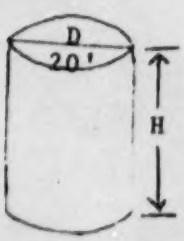
Area of Tanks or Cylinders

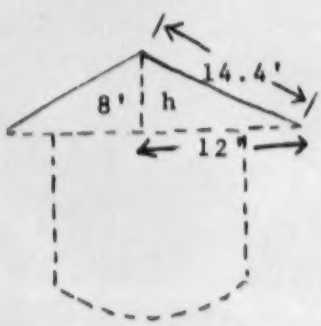
In order to find the area of the walls of a tank or cylinder, the circumference or perimeter is multiplied by the height. Such a calculation would be useful in deciding how much paint would be necessary to coat a tank. The area of the walls of a cylinder is called the "Lateral Area" (A). This term might be more easily understood if thought is given to how a tank might be constructed. Imagine a sheet of steel is 62.8' long and 20' wide. Its area is 62.8 x 20 or 1256.0 sq. ft. Roll this into a cylinder, weld the ends together, and put a bottom on it. The result is a tank 20 feet in diameter, 20 feet deep. Its circumference is D or 3.14 x 20 = 62.8 feet. The area of the wall (called "Lateral Area") would be found by multiplying 62.8' x 20' or 1256 sq. ft. Thus the formula for Lateral Area is:

$A = \Pi D H$
$A = \Pi \times 20 \times 20$
$A = 3.14 \times 20 \times 20$
$A = 1256$ square feet



Lateral Area $A = \Pi D \times H$





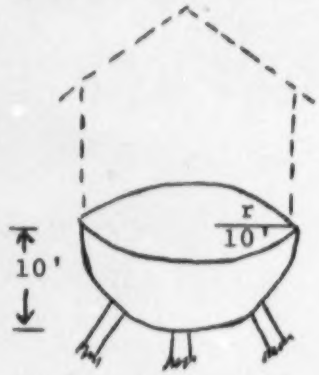
Suppose one gallon of paint will cover only 250 square feet. Then the area (lateral area) divided by 250 will give the number of gallons of paint per coat. 1256 ÷ 250 = 5 gallons needed.

Suppose the tank has a conical top which must also be painted. The area of a cone is found by multiplying the circumference of its base by half of the slant height. The top overhangs the tank 2 feet all around making its diameter 24 feet, rather than 20 feet, so the radius R of the base of the conical top is 12 feet. If measured it would be found that the slant height would be about 14.4 feet. Thus the area is:

$A = 2\pi r \times 1/2$ slant height
$A = 2 \times 3.14 \times 12' \times 7.2' = 542$ sq. ft.

Now, if the tank has a rounded bottom its approximate area can be found by using the formula for half a sphere (ball), which is $A = 4\pi r^2/2 = 2\pi r^2$. Even if the bottom is somewhat off round the same formula should give a good approximation of the area. Multiply the radius of the tank by the circumference. (Remember, circumference = $2\pi r$.)

Area = r x $2\pi r$
A = 10' x 2 x 3.14 x 10'
A = 628 sq. ft.



The total area to be painted is, of course, the sum of these areas (the walls, top and bottom). 1256 + 542 + 628 = 2456 sq. ft. If the tank is to be painted inside and out, the area must be doubled.

The approximate volume of this bottom section, if it is half of a sphere, is 1/4 D^3, as the volume of a sphere (ball) is 1/2 D^3. (1/2 D^3 = $\frac{D \times D \times D}{2}$).

$V = 1/4\ D^3$
$V = \frac{20' \times 20' \times 20'}{4}$
$V = \frac{8{,}000}{4}$
V = 2000 cu. ft.
2000 x 7.5 = 15,000 gallons

By adding this figure to the volume of the cylinder, which was figured above, the total volume of the tank will be 47,000 + 15,000 or approximately 62,000 gallons of water.

DETENTION TIME:

Detention time, sometimes called the retention period, is the length of time water is retained in a vessel or basin. It may also be considered the period from the time the water enters a settling basin until it flows out the other end. To calculate the detention period of a basin, the volume of the basin must be first obtained. Using a basin 20' wide, 60' long and 10' deep the volume would be:

V = L x W x D
V = 60 x 20 x 10
V = 12,000 cu. ft.
Gallons = V x 7.5 gal. per cu. ft.
Gallons = 12,000 x 7.5 = 90,000

Assume that the plant filters 250 g.p.m. Therefore, 90,000 ÷ 250 = 360 minutes or 6 hours detention time. Stated another way, the detention time is the length of time theoretically required for the coagulated water to flow through the basin.

If sufficient chlorine were added to the water as it entered the basin it would be said that the chlorine contact time, <u>in the basin</u>, is six hours.

AREAS AND VOLUMES OF PLANE AND SOLID GEOMETRICAL FIGURES

Area of a circle = πr^2

$2 \pi r$ = Circumference

or

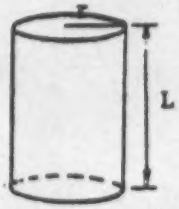
$D \pi$ = Circumference

Area of a sphere =

$4 \pi r^2$

Volume of sphere = $\frac{4}{3} \pi r^2$

$1/6 \pi d^3$



Lateral area of cylinder =

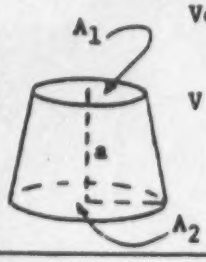
$2 \pi rL$

Volume = $\pi r^2 L$

Volume of cone = $\frac{1}{3} \pi r^2 a$

Volume of pyramid =

$\frac{1}{3}$ x (area of base) x a



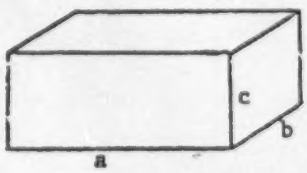
Volume of frustum of cone or pyramid =

$V = \frac{a}{3} (A_1 + A_2 + \sqrt{A_1 A_2})$

A_1 = area of one base

A_2 = area of other base

Volume of cube, retangular basin, or any parallelepiped =



V = area of base x altitude for rectangular objects

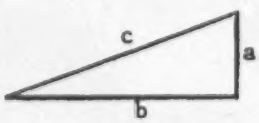
V = a x b x c

Area of any parallelogram =

ba

A = b x a

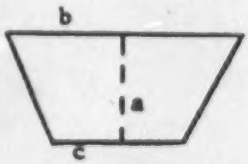
To find the length of a side of a triangle:



The square of the hypotenuse (c) is equal to the sum of the squares of the other two sides for any right triangle.

$c^2 = a^2 + b^2$

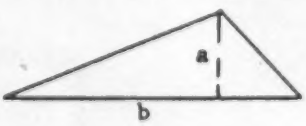
$c = \sqrt{a^2 + b^2}$



Area of a trapezoid =

1/2 (b+c) a

Area of any triangle = 1/2 ba



A = 1/2 b x a

USEFUL CONVERSION FACTORS IN WATER WORKS OPERATION

Miscellaneous Equivalents

1 cu. ft. water = 62.4 lbs.
1 cu. ft. water = 7.48 gallons
1 U.S. Gallon = 231 cu. inches
1 U.S. Gallon = 0.1337 cu. ft.
1 U.S. Gallon = 8.345 lb.
1 U.S. Gallon = 3.785 liters
1 fluid ounce = 1.8047 cu. in.
17.1 ppm = 1 grain per gal.
1 ppm = 8.345 #/million gals.
1 liter = 1000 milliliters (ml)
1 liter = 0.2642 gallons

1 grain per gal. = 142,857 lbs. per million gals.
1 ppm = 0.0584 grains per gal.
1 ppm = 1 lb. per 120,000 gals.
1 cu. ft. per second = 448.83 U.S. gpm
1 M.G.D. = 700 gpm (694.4 gpm exact)

Lineal Equivalents

1 foot = 12 inches
1 yard = 3 feet
1 mile = 5,280 feet
1 inch = 2.54 cm.
1 foot = 0.3048 meters
1 cm. = 0.39370 inches
1 meter = 3.28 feet

Area Equivalents

1 sq. ft. = 144 sq. inches
1 sq. yd. = 9 sq. ft.
1 Acre = 43,560 sq. ft.
1 sq. cm. = 0.155 sq. in.
1 sq. in. = 6.45 sq. cm.
1 sq. meter = 10.75 sq. ft.
1 sq. foot = 0.0929 sq. meter

Weight Equivalents

1 lb. Water = 27.68 cu. in.
1 lb. Water = 0.1198 U.S. Gallon
1 lb. Water = 0.4536 Liter
1 gram = 15.43 Grains
1 gram = 0.0353 Ounce
1 kilogram = 1000 grams
1 kilogram = 2.205 Pounds
1 Ounce = 28.35 Grams
1 Pound = 16 Ounces
1 Pound = 7000 Grains
1 Pound = 453.6 Grams
1 Ton = 2000 Pounds

Volume and Capacity Equivalents

1 Gal. = 4 qts. = 231 cu. inches
1 Qt. = 2 Pts.
1 cu. in. = 16.387 cu. cm.
1 cu. cm. = 0.061 cu. in.
1 Liter = 61.023 cu. in.
1 Liter = 0.0353 cu. ft.
1 Liter = 0.264 Gallons
1 Liq. ounce = 29.57 milliliters
1 Liq. qt. = 0.946 liters
1 cu. ft. = 28.317 liters
1 cu. yd. = 27 cu. feet
1 acre foot = 43,560 cu. ft.

1 lb. per sq. in. = 2.307 ft. of water
0.4334 #/sq. in. = 1 ft. of water
1 atmosphere = 14.7 p.s.i, (absolute)
14.7 p.s.i. = 29.92" of mercury
29.92" of mercury = 33.9 feet of water
33.9 feet of water = 760 m.m. of mercury
760 m.m. of mercury = 1 atmosphere
1 HP = 33,000 ft. lbs. per minute
1 HP = 0.746 KW

SOURCES OF WATER*

Our sources of drinking water may be divided into three more or less arbitrary and overlapping groups: *rain water, surface water,* and *ground water.* Of course, when water falls as rain it immediately becomes surface water, unless caught in a cistern or tank, and part of it enters the soil and becomes ground water. Ground water, in turn, sooner or later comes to the surface and is again surface water, some of which evaporates and rises in the atmosphere to fall again as rain. This cycling of water from the clouds to the earth and back to the clouds is known as the hydrologic cycle.

The average rainfall for the entire United States is about 30 inches. About 21 inches returns to the atmosphere, part by direct evaporation and part by transpiration. Only 9 inches becomes available as surface or ground water. We use only 3 inches or about 10% of the average rainfall.

However of the water withdrawn by man, very little is used for domestic purposes. Over 90% of this water is used for irrigation or industrial uses. Consumptive use is water that evaporates or is incorporated into a product. Nonconsumptive use indicates that the water is returned to the environment for reuse.

Rain Water

Theoretically, rain water should be the purest of all natural waters. Water vapor rising from the sea in the form of clouds condenses and falls as rain, snow, or hail. This is really a process of distillation, and the only impurities the water may gather in condensing and falling are atmospheric gases, dust particles, and air-borne organisms. Rain water is *soft* and therefore valuable for laundry purposes. Because the source is liable to fail when needed, and because of the difficulties of proper storage, rain water for drinking purposes is not favored.

In the first place, its storage place is subject to contamination. The fact that it cannot be collected in large enough quantities for municipal supplies leads to the dangerous practice of having a private underground cistern too near a house or barn, where it is almost impossible to avoid pollution by seepage of wastewater through the surrounding soil.

*Source: Correspondence Course Manual for Water Plant Operators Class D, Second Edition, The South Carolina Water and Pollution Control Association, pp. 164-174.

Since disease producing organisms are sometimes able to survive the previous drying necessary for them to get into the air, and hence into properly protected cisterns, the storing of rain water may be an indirect means of transmission of disease. Certain insects, for example the yellow fever mosquito, may breed in soft water cisterns. Yellow fever, like malaria, is transmitted only through the mosquito. If the breeding place of the mosquito is abolished, the means by which the disease is transmitted is thereby destroyed. Yellow fever was epidemic in some seaport towns such as Philadelphia and Boston before the cistern was suppressed by law.

Surface Water

Ponds, lakes, reservoirs, small streams, and rivers are classified as surface water. Most cities in the United States receive their water supply from surface water, since most towns were founded along a river or stream in order to secure an adequate supply. It is quite natural, therefore, that this large and unfailing supply of water at the very gates of the town should be looked on as a source of drinking water. Yet, scientific discoveries and experiences involving losses of lives and money have demonstrated that a great danger exists in the easily obtainable supply. It must be remembered that very few rivers supply a single city. Since the upstream population frequently uses the river not only for its water source, but for its wastewater disposal as well, the river becomes the natural continuation of the alimentary tract of the upstream population to the downstream population.

Many state and federal laws are being passed forbidding upstream cities to pollute a river which later flows by another city. If it were possible to make certain that all pollution entering a stream came through the sanitary sewers of the city, such a plan might be practical, but contamination from outlying communities and individual houses, or boating make reliance on wastewater purification unsafe.

Again, the stream may be accepted as a polluted supply and the water may be purified by the use of chemicals and filtration. This is the most common practice today. Millions of dollars are spent annually in purifying municipal water supplies. If bacterial contamination was the only objectionable substance in river water, this procedure would probably suffice. This, however, is not true. Factory wastes, packing house debris, and other impurities do get into streams in spite of laws. Moreover, a stream dissolves chemical substances from the channels through which it flows. These substances, or their oxidation products, are undesirable at the least. Such materials are not eliminated by bacterial *purification* methods.

Ponds, lakes and artificial lakes (or reservoirs) are the most desirable water supplies. The comparative ease in watching the catchment areas greatly simplifies the purification procedures. However, freedom from pollution must never be taken for granted.

Small cities and towns situated near mountain lakes or easily dammed mountain streams are very fortunate. The chief disadvantage of this source of supply is the possible outgrowth of algae and protozoa in the reservoir, which may give the water a disagreeable odor or taste. Proper treatment with an algaecide, such as copper sulfate, will usually obviate this trouble. Another cause of disagreeable odors and tastes in impounded water is what is popularly called *overturning*. This situation occurs twice a year, in the spring and fall, at a time when the temperature of the water in the lake is uniform from top to bottom.

Large lakes are also frequently used not only as a source of the cities' water supplies, but also as an outlet for their wastewater systems. Lake Erie has been receiving inadequately treated wastewaters from industry and municipalities for many years and is now in an advanced state of pollution. Even if immediate action is taken to reduce the inflow of pollutional substances into Lake Erie, it will take many decades to restore the Lake to a healthy condition.

Leopold and Langbein* have prepared a very good review of the sources of water. This booklet is available for only $0.35 from the U. S. Government Printing Office.

Ground Water

Ground water is obtained from three sources: first from shallow wells; second, from deep or artesian wells; and third, from springs. Shallow wells should be properly placed and properly watched, since the water that finds its way into these wells is mostly seepage from the surrounding ground surface. All possible care should be taken to avoid contamination from house or barn drainage. The possibilities of shallow well pollution from a cesspool depend on several factors of which distance, type of soil, character of underlying rock, and level of permanent ground water are the most important. Bacteria causing intestinal disease have been known to survive in moist soil for more than two months. In a dry soil of uniform texture, free from cracks or fissures, the bacteria from the intestinal tract, even in a heavily polluted area, will not penetrate more than the depth of 10 or 12 feet, and horizontally not more than 3 or 4 feet. Therefore, in a fairly dry, loose soil, in which the level of water is

*Leopold, L. B., and W. B. Langbein, 1960. *A Primer on Water*, Supt. of Documents, U. S. Government Printing Office, Washington D. C., 35¢.

more than 10 feet below the surface of the ground, there is only slight danger from seepage. There is always, of course, danger from surface drainage. In a clay or other packed soil where fissures are possible, or in a soil where the level of permanent ground water rises to within a few feet of the surface, the menace is real at a considerable distance.

Shallow wells are seldom the source of supply for a municipality. They may be used for small supplies in rural areas. An excellent review of the problems and solutions associated with small scale water supply systems is available in Public Health Service Publication No. 24. This is available from the U. S. Government Printing Office for $0.40.

Deep wells and artesian wells are generally considered to be the safest source for drinking water supplies, and generally speaking, this is true. However, there are special circumstances which may result in the pollution of these wells also. A deep well drilled through porous rock like limestone may be no purer than a shallow well since the water trickles downward through the large pores in the limestone formation with only slight filtering action. An artesian well likewise may become contaminated if the impervious layer through which it was drilled comes to the surface at some distance from the well and permits polluted surface water to drain under that layer and into the underlying water-bearing strata which feeds the well.

So-called *springs* are sources of water that result from the seepage of water downward through the soil until it strikes an impervious layer of soil or rock. If this impervious layer is on an incline, the water will then flow along over the top of the impervious material until it finds an opening and then it will continue its downward journey. If the impervious layer terminates on the side of a hill, then water flows out on the surface and may be captured and stored. This water may or may not be safe to drink. If it has passed through an adequate layer of soil of proper texture having good filering properties, and the catchment has not been unduly exposed to pollution, it will most likely be quite satisfactory. On the other hand, if it has passed through material of relatively coarse porosity, the purity of the water will not be greatly changed. Careful survey of the drainage area from which a spring arises, along with a study of the geological formations of the surrounding terrain, should be made by competent individuals before the water from a spring is recommended for domestic use.

RECORDS AND REPORTS*

Records

Importance of Records. Keeping of adequate records of performance is an integral part of good water treatment plant operation. Only by making a clear and concise memorandum of what has happened and what has been accomplished will the experiences be of assistance in meeting future operation situations. Pertinent and complete records are a necessary aid to control procedures. Above all, records should be used as a basis for plant operation and for interpreting the results of water treatment.

Records also provide an excellent check on things done or to be done, especially regarding maintenance problems. Equipment in water treatment plants requires periodic service; some daily, some weekly, and others monthly or yearly. Adequate records show when service was last performed and when the time for service approaches. Thus a schedule can be maintained, with nothing overlooked or forgotten.

Significant details of day-to-day experience provide a running account of plant operation and thus have an important historical value. When accurately kept, records provide an essential basis for the design of future changes or expansions of the treatment plant and also can be used to aid in the design of water treatment facilities for other locations where similar problems may be encountered. In the event of legal questions in connection with water treatment or plant operations, accurate and complete records would be urgently required as evidence of what actually occurred at any given time or over any particular period of time. Thus, records and their proper maintenance are essential in any type of water treatment. However, only those records should be kept which are known to be useful; the temptation to accumulate minutiae of no significant value must be guarded against.

In summary, the main functions of records are:

To satisfy legal requirements

To provide an alert for changing raw water quality

To aid the operator in solving treatment problems

To show that the final product is acceptable to the consumer

*Source: Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Health Education Service, P.O. Box 7283, Albany, N. Y. 12224. Chapter 18.

To show that the final product meets plant performance standards

To show that the final product complies with the West Virginia Drinking Water Standards

To determine equipment, plant, and unit process performance

To aid in answering complaints

To anticipate routine maintenance

To provide cost analysis data

To provide future engineering design data

To provide the basis for monthly or annual reports

Information To Be Included. The extent to which record keeping should be practiced depends entirely upon their potential use. The type of treatment, the volume of water treated, and the kind and importance of installations auxiliary to the treatment plant will control the amount of necessary record keeping.

Some of the basic items of information to be recorded are:

Surface Source

Air temperature
Raw water temperature
Rainfall data
Runoff data
Height of reservoir vs. storage
Capacity
Raw water quality
Raw water quantity used
Quantity of raw water released for riparian users
Actions taken when spills occur

Ground Source

Raw water temperature
Raw water quality
Well logs
Static levels
Pump test data
Pump performance curves
Drawdown levels
Observation well data
Quantity pumped
Pumping intervals
Recovery rates

Treatment

Amount of water treated with chemicals
Chemical dosage; pounds per hr., pounds per day
Total amounts of chemical used
Amount of water filtered
Number of filters in service
Number of hours filters are in service
Final loss of head before filter was washed
Amount of washwater used
Length of time washwater was applied
Rate of wash
Cycle times for diatomaceous earth filters, pressure, sand, etc.
Daily or more frequent results of chemical, physical, and bacteriological laboratory tests
Minimum, average, maximum figures for laboratory testing

Pumping Stations

Total amount of water delivered by each pump
Suction and discharge pressures
Number of hours of pump operation
Daily power consumption

Other

Maintenance schedules
Distribution system pressures
Master and individual meter readings
New valve and hydrant installations

In addition to these basic data items, each water supply system should have:

Hydrant and valve maps for the distribution system

A list of material and equipment suppliers

A central file of instruction manuals for treatment equipment or processes; operational guides for waste control facilities

All records required by the Public Water Supply Regulations

A description of the basic functions of automatic control systems

A safety program

Cross connections control plan

Engineering plans and specifications for past construction

Names, addresses, and telephone numbers of nearby operators and personnel of the city, county, district, or regional health office

Copies of the watershed rules and the latest watershed inspection report

The procedure for adjustments necessary in case of a major fire

The above are just a few of the many data items that make up good records. Each water supply system has its own critical areas for which data are necessary.

When laboratory determinations are made, it is essential that not only the final results of each test be recorded, but also that all of the test data, frequently called the working data, such as buret readings and the necessary computations, be noted for future reference. Although such details may seem superfluous, should any question arise as to the accuracy of final data obtained in the laboratory, the notes on technical procedures, if available, will be evidence of the accuracy or inaccuracy of the final result reported. Thus, for his own protection in maintaining the integrity of his work, the analyst in the laboratory should keep complete records in most cases. This means that full records of tests must be maintained in the laboratory, although the separate plant operation records will contain only the final result of such laboratory determinations.

Frequently, state and municipal regulations govern the operation of water treatment installations. These regulations require that certain operating records be maintained and reported to the supervising agency at specified intervals. These records must be kept, but should be in addition to adequate plant operating data and should not be considered a substitute for plant records.

How Records Should Be Kept. Record systems can be either simple or complex. However, they should be realistic and apply to the operating problems involved at each particular treatment facility.

The most efficient way to keep records is to plan what data are essential and useful and then to prepare forms on which the information may be quickly entered in the proper spaces. Forms not only indicate the data to be obtained but provide for entering them with a minimum possibility of error or omission. Prepared forms can be used both for plant operations and for laboratory determinations. To keep records without the use of well designed forms increases the labor and time involved and promotes inaccuracies. It must be remembered that inaccurate or incomplete records are worse than no records at all. Business firms specializing in the printing of forms usually have staff trained to give advice in setting up records systems and choosing the type of form best suited to the need. Forms in use at treatment plants of a similar type are useful in preparing forms, and can be obtained on request.

Records should be permanent, and consequently entries on the forms should be made with ink or with indelible pencil. Ordinary lead pencil notations smudge easily and can be too readily erased or altered; a lead pencil should never be used.

Once made, records of any type should be carefully preserved and filed where they can be located rapidly. This requires the establishment of a filing system that will be used and understood by everyone concerned with making and using records. The corollary is that filing of completed record forms must be attended to promptly and with care. A record misfiled is a record lost, and a lost record is of no value.

A pertinent question which always arises is how long records should be kept. Obviously, they should be kept as long as they may be useful, with due consideration given to the historical value of some types of data. Some information will have little utility after a short time, while other information may be found of great value even after the passage of many years.

Any data that might be used in future as a basis of design for plant expansion or for new construction should be kept indefinitely. Results of laboratory analyses will always be pertinent and likewise should be kept indefinitely. Detailed operating data related to a given treatment device may have little permanent significance and can be kept for a year, or some indicated period, and then discarded. Official approval is required before some types of records can be discarded or destroyed. The fact that old records are not consulted every day in no way lessens their potential value. It is the best modern practice to set up a disposal schedule for each type of record maintained in order to avoid the accumulation of useless files. A decision can be made at the time a record is set up limiting the period for which it must be available.

Records must be stored in a manner to insure their permanence and safety, as well as their accessibility.

Records should be made at the time the data are obtained by the person directly concerned with making the particular measurements. Responsibility for proper filing, care, and use of records will rest with the supervisor or the person in charge of the treatment plant, or someone delegated by him.

Reports

With the accumulation of all essential data including authentic records in the manner outlined above, the basis or groundwork for the report is established. Just as the maintenance of complete and accurate records can be of definite value in the evaluation of water treatment performance, the development of the report is of inestimable value for many reasons.

In the preparation of a report, the period to be covered, such as monthly, quarterly or annually, shall be predetermined. For all practical purposes, in the consideration of water treatment plant operation and performance, a report on an annual basis not only appears to be the most widely accepted but also the most effective in advising and informing the governing body--the village board, city council or the board of water commissioners--on the status of the water system and water treatment plant. The report should not only include data on the effectiveness of water treatment but also information on the cost of labor, chemicals and power and on any other items that may have a bearing on the water treatment plant operation.

Another very important reason for an annual report of the operation of a water treatment plant is the education of the public. Operators should obtain the cooperation of their respective governing bodies in making available to the local news media a copy of the report each year.

Reports should be accurate, complete and understandable. Some points that should be considered in the preparation of a report include:

1. Introduction---This should be merely a few short sentences or paragraphs to provide a background for the reader.
2. Body---This should include a description of the various components in the treatment process, statements on the quantities of labor, chemicals, power, etc., used and the flow. Charts or tables to illustrate the narrative portion should be included. It is desirable to include appropriate photographs of plant components to make the report more understandable.
3. Conclusion---This should be a summary of the items in the body of the report. Appropriate statements should be made in the form of recommendations to correct any deficiencies mentioned in the report.